NCSP Technical Briefing

Sub-Critical Neutron Measurements Using Active Interrogation Techniques

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Use of Active Techniques For Performing Benchmark Measurements

▪Higher quality measurement data is obtained on low intrinsic neutron source systems if there are limitations on measurement times and/or detection efficiency.

▪An active measurement is more difficult to model, but it also presents an opportunity to benchmark further code development and associated data.

1. Modeling of source and object interactions using associated data
2. Time-dependent fission product distributions
3. More complicated modeling and analysis of list-mode data acquisition

An active measurement may provide an opportunity to measure an observable which can be of use as part of the benchmark evaluation process which would not be obtainable to measure when performing a passive measurement.

Technical Contributors

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Delayed Neutron Re-interrogation Physics

▪**Pulsed external source initiates fission chains in uranium**

▪**Zetatron (14 MeV D-T neutrons) and LINAC (10 MeV Bremsstrahlung photons) active measurements performed at TA-18 interrogating sub-critical configurations of Rocky Flats HEU metal Critical Assembly parts.**

Photoneutron/Photofission Reaction Threshold Energies

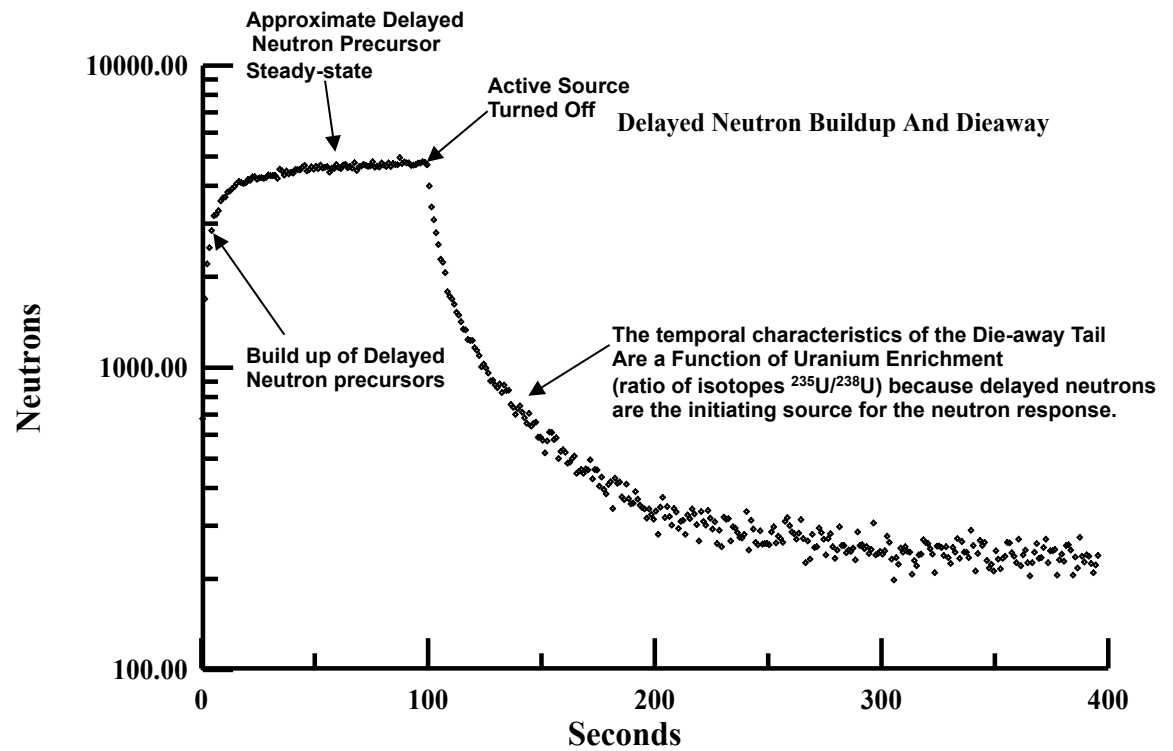TABLE 3.1 REPRESENTATIVE PHOTONEUTRON/PHOTOFISSION PRODUCTION NUCLIDES

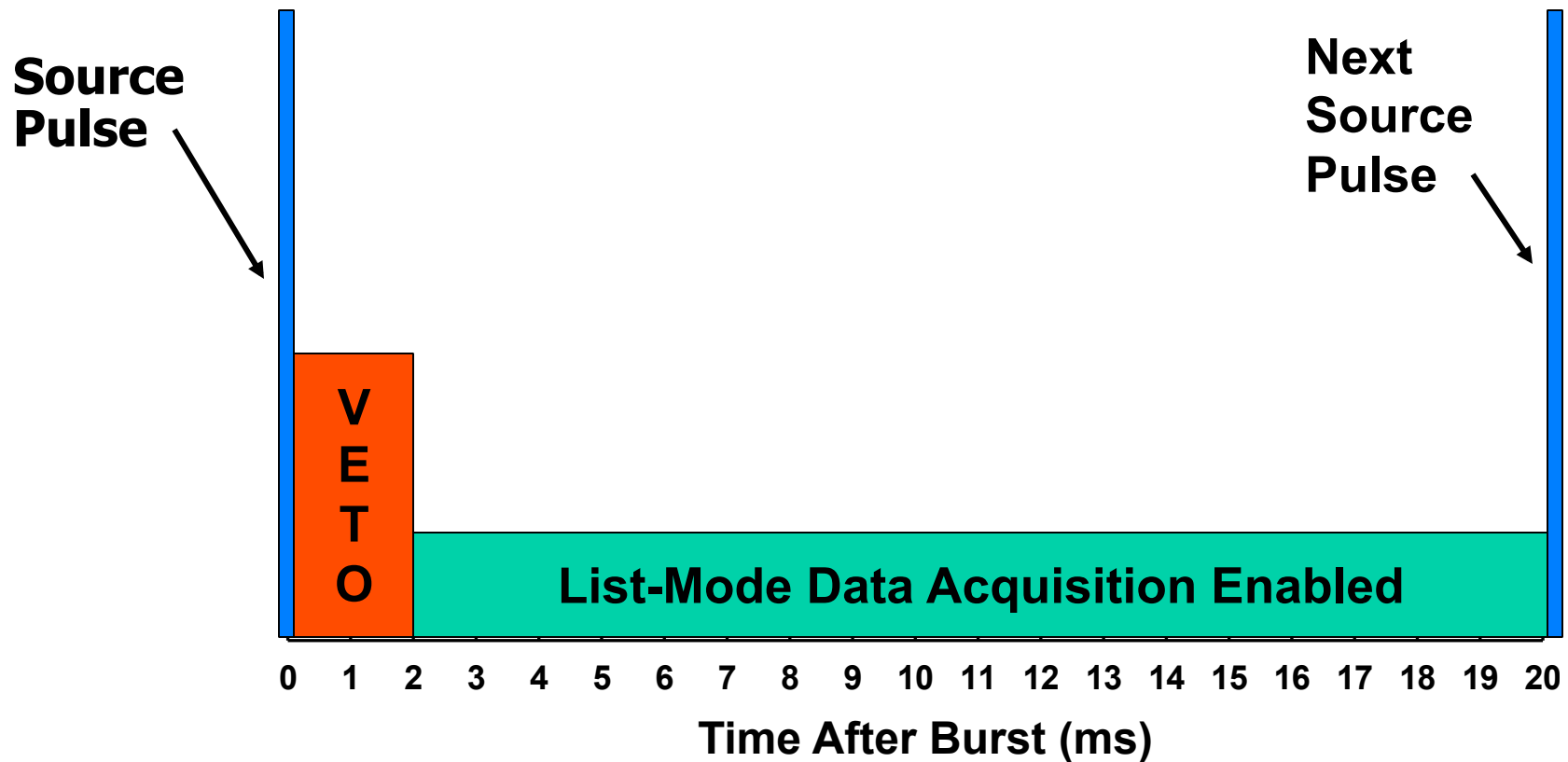| Element/Isotopes	Percent Nat. Abundance	(γ,n) Threshold (MeV)
General Nuclei		
H-2	0.02	2.2
Li-6	7.5	5.6
Li-7	92.5	7.3
Be-9	100.	1.7
C-12	98.89	18.7
C-13	1.11	4.9
N-14	99.63	10.6
N-15	0.37	10.8
O-16	98.76	15.7
O-17	0.04	4.1
O-18	0.20	8.0
Nuclear Nuclei		
Pu-239	-	5.6 [5.6]⁺
Pu-240	-	6.5 [6.1]
Pu-241	-	5.3 [5.4]
U-232	.	7.3 [6.7]
U-233	.	5.7 [6.0]
U-235	0.72	5.3 [5.8]
U-236	.	6.5 [5.9]
U-238	99.27	6.1 [5.8]
Th-232	100.	6.4 [6.0]
Structural Nuclei		
Cu-63	69.2	10.8
Cu-65	30.8	9.9
Fe-54	91.8	11.2
Fe-56	2.1	7.6
Fe-58	0.3	10.0
W-182	26.3	8.0
W-183	14.3	6.2
W-184	30.7	7.5
W-186	28.6	7.3
Al-27	100.	13.1
Ca-40	96.94	15.7
Ca-43	0.14	7.9
Ca-44	2.09	11.1
Si-28	92.2	17.2

Delayed Neutron Re-interrogation Physics (continued)

- Fission products get distributed throughout the uranium.

- Delayed neutron emission follows the beta decay of a fraction of the fission products.

- Delayed neutron emission occurs randomly and later in time with respect to the parent fission.

- Delayed neutrons either leak from the system or initiate further fission chains.

Delayed Neutron Re-interrogation Physics (continued)

- **After a finite number of active pulses, the delayed neutron precursor populations reach apparent steady-state levels.**

- **Continued interrogation results in near steady-state source of neutrons that is distributed throughout the uranium that re-interrogates the material.**

Approximate Delayed Neutron Precursor Steady-state

Active Source Turned Off

Delayed Neutron Buildup And Dieaway

10000.00

Neutrons

Build up of Delayed Neutron precursors

The temporal characteristics of the Die-away Tail Are a Function of Uranium Enrichment (ratio of isotopes $^{235}U/^{238}U$) because delayed neutrons are the initiating source for the neutron response.

1000.00

100.00

0   100   200   300   400

Seconds

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Pulsed Active Source Measurement Protocol

Source Pulse

Next Source Pulse

V E T O

List-Mode Data Acquisition Enabled

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Time After Burst (ms)

Summary of Active Sub-critical Neutron Measurement Data Utilization

- An active Sub-critical measurement interpretation and modeling effort can be more complex than a passive sub-critical neutron measurement.

- Complexity can introduce the opportunity to evaluate more code development and its associated data.

- Opportunity to evaluate data and sampling methods or models associated with the source/system interactions that are not possible during passive sub-critical neutron measurement evaluations.

- Opportunity to measure observables to compare with computational results That would not be possible during a passive measurement. (some dynamic Reactor physics parameters that can be calculated)